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Biological Control as a Management Strategy in the Great Lakes[1]

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ABSTRACT

Nuisances in Great Lake environments have most often been attacked through the use of chemicals or other unnatural means. Although many of these nuisances are economically undesirable, in order to sustain our natural resources we must develop convergent strategies that do not achieve economic goals at the expense of the environment. With the increased awareness of biotechnology more attention should be paid to developing, adapting, and exploiting characteristics of Great Lake ecosystems that will contribute to the biological control of nuisances. This paper discusses alternatives to present management strategies focusing on the use of natural biological systems to mitigate or eliminate nuisances such as aquatic weeds and sea lamprey, rather than intervening with unnatural solutions after problems reach crisis levels. Discussion emphasizes the control of aquatic weed growth through enhanced grazing by crayfish and the control of sea lamprey parasitism on game fish through predation by Lake Sturgeon. It is hoped this paper will demonstrate that biological controls applied to problems facing Great Lake natural resource managers may show merit and be worth considering. If feasible, these strategies will provide management options that emphasize sustainability of our natural resources.

Introduction

The environment within which we live is an arrangement of independent and yet cooperating systems that in one way or another support much of man's economic growth. To develop a philosophy of sustainability for our natural resources requires the development of convergent strategies that minimize having to choose between environmental and economic alternatives and maximize the achievement of economic and environmental goals in concert. As we have already learned through numerous case histories, over the long-term, deterioration in environmental systems translates to deterioration in economic systems. Therefore, we must reevaluate management policies that emphasize maximum benefit from natural resources at the expense of the environment that supports these natural resources.

Biotechnology includes a collage of different research areas and encompasses a diversity of means for using living matter to develop useful products, including the exploitation of biological processes occurring in

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nature for the benefits of man and the environment. The National Science Foundation defines biotechnology to include the "controlled use of biological agents, such as organisms or cellular components, for beneficial application" (Markle and Robin, 1985) *Biological control*, which is an extension of biotechnology, is largely based upon processes that occur continually in nature. Cotton, one of the most developed insecticide-intensive crops, serves as a good example of the benefits derived from biological control methodology. Cotton hosts more than 25 resistant anthropods, many of which seriously damage crops only after their natural predators have been eradicated by the same chemical controls (Mlot, 1985). Alternative pest control strategies are being developed for this industry in order to prevent (1) genetic selection in the pests leading to eventual resistance to chemicals and (2) harmful effects to other components of the environment that might otherwise aid in control of the pests (*i.e.* death of natural predators). The results of this research into cotton pest control has been the development of Integrated Pest Management (IPM; Frisbie and Adkisson, 1985) where, among other strategies, insect pest populations are monitored to gauge resistance to chemical treatment and beneficial (predator) insects are stimulated to compete with the pests, *i.e.,* biological control.

Through history, there have been other biological control strategies applied to environmental problems. The killifish, *Fundulus heteroclitus*, was examined for its ability to control mosquito populations (in the larval stage) in Long Island, New York (Chidester, 1916). Because of the success of this fish in feeding on larvae of mosquitos and green-head flies, artificial stocking was proposed as a control to the nuisance. Gypsy moths serve as another example of biological controls lessening a pest's impact (Beroza and Knipling, 1972). The use of the species' own sex pheromone served as a means of trapping males of the populations and breaking the reproductive cycle of the pest. Perhaps the most recent example of biological control in the aquatic environment is the manipulation of trophic levels to eliminate or control nuisance populations (pests) in lake ecosystems. Fish and zooplankton populations have been manipulated to biologically control nuisance phytoplankton (Shapiro, 1982; Vanni, 1984; Spencer and King, 1984). Salmonid stocking programs in the Great Lakes were initiated, among other reasons, to biologically control the abundant alewife populations and reduce the nuisance of massive annual die-offs of this species. The cascading effect of this control has been reduced predation on zooplankton by the alewife (Eck and Brown, 1985) and in turn, smaller phytoplankton standing stocks (food of zooplankton), resulting in clearer waters for Lake Michigan (D. Scavia, 1984; D. Scavia, Great Lakes Environmental Research Laboratory, personal communication, 1985).

Disturbances to Great Lake environments, which have impacted man's use of these resources, have most often been attacked through an interventive approach. For example, the accumulation of toxic compounds within the food chain of Lake Ontario resulted in the ban of human consumption of many fish species. Likewise, the offensive growth of aquatic weeds and macroalgae along the lakeshores has been controlled through harvesting or with the use of herbicide chemicals. Another nuisance to Great Lake environments has been the sea lamprey and its parasitic attack on stocked salmonids sought by recreational fisherpersons. This problem has been attacked by use of toxic poisons as an interventive control strategy, at the expense of the habitats in which lamprey spawn. To protect the large investments in fish stocking and create suitable waters for recreational boating, management responses to these and other Great Lake environmental problems have been reactive (interventive), usually through chemical or other unnatural means, rather than preventative, where action is taken before the particular problem reaches a crisis level.

With the advent of biotechnology more attention should be paid to the concept of developing, adapting, and exploiting natural biological characteristics of the Great Lakes to address the ever-growing problems associated with these ecosystems. It is recognized that aquatic systems are quite resilient and capable of tapping their own resources to recover and adapt from perturbations (*e.g.*, Harrison 1979; Deangelis 1980). This recognition suggests that man work with ecosystem characteristics for the enhancement of natural attributes that will contribute to the biological control of disturbances. Consider, for instance, that crayfish have the potential in lake systems to control aquatic weeds. Is it possible that by promoting crayfish populations need for using chemical or mechanical controls in weed-choked lake embayments could be reduced? It is also known that sea lamprey are used as bait by sturgeon fishermen in midwestern lakes. Sturgeon were all but eliminated in the Great Lakes at about the time the sea lamprey made significant inroads. Is it possible that the benthos-feeding sturgeon could significantly reduce sea lamprey populations before their parasitic stage, thereby reducing the need for chemical controls?

Biological control strategies have proved extremely successful in the management of terrestrial environmental problems (*e.g.* pests). In addition, lessons from terrestrial case histories tell us that continued reliance on chemical control of pests such as aquatic weeds and sea lamprey will ultimately result in genetic selection for resistance against treatment and/or inhibition of natural predator effects. Terrestrial approaches to biological control can serve as a model to begin formulating solutions for freshwater nuisances. We suggest that biological controls are viable strategies for the management of several pressing problems that haunt Great Lake environments. Thoughts on a couple of potential strategies are discussed below.

Aquatic Weed Control

The effects of grazing on aquatic vegetation have been extensively studied. Kajak and Warda (1968) and Paine and Vadas (1969) showed a definite effect of grazing on the productivity of attached benthic flora. Castenholz (1961) compared the diatom cover which developed in ungrazed intertidal areas with that in adjacent areas of controlled grazing by limpets. Cooper (1973) observed reduction in producer standing crops by grazing of a starved herbivore, *Notropis spilopterous*. Grass carp (*Ctenopharyngodon idella*) have been observed to graze heavily on submerged macrophytes and eliminate populations of these plants from sublittoral areas of lakes (Shireman and Maceina, 1981). Herbivory on macrophytes by crayfish in freshwater has also been documented. Intense grazing by a dense population of crayfish (*Astacus astacus*) was responsible for the control of submerged vegetation of ponds in Sweden (Abrahamsson 1966). Dean (1969) found a decrease in aquatic weeds to be related to high crayfish densities. Flint and Goldman (1975) observed that crayfish (*Pacifastacus leniusculus*) reduced the biomass of *Myriophyllum* in the clear waters of Lake Tahoe. Lorman and Magnuson (1978) and Lodge (Univ. Wisconsin, personal communication, 1984) noted that even low densities of the crayfish *Orconectes rusticus* reduced macrophytes. They manipulated the density of this crayfish in four replicated enclosure-exclosure experiments in the littoral zones (1–3 m depths) of three northern Wisconsin lakes. In Trout Lake, natural densities of crayfish reduced macrophyte stem number by about 50% (1 crayfish/m^2), 80% (5/m^2), and 100% (10/m^2). In all experiments, macrophyte species number was also reduced.

Littoral zones are essential for growth and survival of many species and the structural heterogeneity created by macrophytes is one of the reasons they are important lake habitats. Some restoration techniques, focusing on macrophyte removal, destroy littoral zones by the use of herbicides and mechanical harvesting. Other technology involves the use of grass carp (*Ctenopharyngodon idella*) to manage submerged weeds. These grazers are capable of completely eliminating weeds in a relatively short time interval. Structurally complex habitats thus become relatively simple areas. Complete weed removal has been shown to cause problems within the lake ecosystem, such as greater availability of nutrients to support nuisance phytoplankton blooms in the water (Carpenter *et al.*, 1983). Other observations have indicated that submerged macrophyte removal appears to disrupt food web stability by reducing predation on zooplankton, creating a size shift to larger zooplankton, reducing phosphorus recycling and thus affecting phytoplankton production (Loucks, 1985).

Crayfish population manipulations could provide a less harmful and more natural solution to controlling macrophyte growth. They do not completely remove weeds but rather control their densities (Flint and Goldman, 1975) below nuisance levels. Despite widespread crayfish abundance, no examples exist of the use of these grazers to control nuisance macrophytic growths in littoral areas of the Great Lakes. In general, these decapods populate estuary and embayment regions, where shoreline development is usually greatest and man has most consistent contact with the aquatic environment. These are also areas that routinely cause greatest concern as a nuisance to boating and unaesthetic appearance of shallow water weed overgrowth. Historical literature indicates crayfish may serve as a biological control for macrophytic overpopulation. Recently manipulation of higher trophic levels (zooplankton and fish) to control nuisance phytoplankton biologically has been illustrated (Shapiro and Wright, 1984; Spencer and King, 1984). The questions to address for crayfish are: 1) why does crayfish control of excessive macrophyte growth not occur in many regions of the Great Lakes where there are problems, and 2) what manipulations can be considered using crayfish populations as a controlling mechanism to offensive aquatic weed growth?

Sea Lamprey Control

Predation by sea lampreys (*Petromyzon marinus*) has long been recognized as a significant mortality source of fish in the Great Lakes, although historical data do not quantify the actual role of this predation in the decline of native fish stocks (Christie and Kolenosky, 1980; Pearce *et al.*, 1980). Interest in sea lamprey control increased following invasion of the upper Great Lakes in the late 1930's, which was in part responsible for the formation of the Great Lakes Fisheries Commission (GLFC) in 1955. Among other responsibilities, the GLFC developed measures and implemented programs to decrease effects of sea lamprey in the Great Lakes, which by 1958 had resulted in control methods utilizing selective chemical toxicants to destroy lamprey ammocoetes (larvae) in their stream habitat (Smith and Tibbles, 1980). Despite the recognized threat from predation, salmonid restoration in Lake Ontario was initiated in 1968 without lamprey control. Impact assessments later indicated significant effects of sea lamprey predation on adult salmonid populations and stimulated a program which now chemically treats identified lamprey spawning tributaries every 3–5 years. Despite implemented controls, lamprey attacks and mortality on salmonids through 1983 were still considered excessive (Eckert, 1984).

Sawyer (1980) was the first to suggest that there may be other, more natural, means of controlling sea lamprey in the Great Lakes than relying on chemical treatment which impacts more than just the target species. He borrowed the approach of "Integrated Pest Management" for sea lamprey control, which included examining the manipulation of natural ecosystem characteristics to effectively limit lamprey impacts. As described previously, the control of pests to terrestrial crop production has relied upon this approach for years and the successes in these areas suggest biological control of the sea lamprey may ultimately be possible.

Comparative species evaluation for similar population dynamics may suggest alternative management techniques that can be applied to control sea lamprey in the Great Lakes. If the missing mortality factor is the lack of natural enemies, then the manipulation of the ecosystem by introduction and/or enhancement of predators could be the solution. One potential candidate to utilize as a biological control for sea lamprey is the Lake Sturgeon (*Acipenser fulvenscens*). This species is extremely rare in most Great Lake environments and has been since the early 1900's, which correlates with sea lamprey invasion. The life cycle of the sturgeon, which includes spawning in tributaries, overlaps the distribution of sea lamprey ammocoetes during their developmental stages in tributary sediments. In addition, the sturgeon feeds off the benthos where ammocoetes are growing before transition to parasitic phases. Anecdotal information is available that indicates sea lamprey are used as bait by fishermen for Lake Sturgeon in many western lakes. Biological control, either alone or in concert with chemical treatment, which is not environmentally sound or universally effective by itself, in that it impacts other populations besides lamprey, presents a viable alternative to present sea lamprey management. Alternative strategies deserve investigation and the use of Lake Sturgeon as a biological control warrants consideration.

Discussion

The goal of this presentation has been to stimulate thought concerning the need to begin considering alternative means of solving Great Lake environmental problems in order to preserve these valuable natural resources. Although many management strategies presently applied to solve Great Lake disturbances are somewhat successful with respect to the target problem, many of these strategies are reactive and stop-gap in nature. In addition, these solutions often do not address the overall sustainability of the ecosystem. Recent success of biological control strategies applied to terrestrial problems demonstrates the need for considering them in aquatic environments that now are managed through some of the same dependencies on chemical/physical control concepts previously applied to terrestrial nuisances.

The consideration of biological control strategies to manage Great Lake resources also answers the long overdue cry for an ecosystem approach to management of natural resources (*e.g.*, Risser, 1985). If manipulations of crayfish populations are a viable alternative to the artificial harvest and herbicide treatment of aquatic weeds, then an additional benefit is to be realized. Crayfish are a food source of many warm-water fish sought by recreational fishermen. In addition, crayfish are sought both as a food and as bait for the booming sport fishery industry in the Great Lakes. Therefore, potential benefits to be derived from crayfish stocking as a biological control could include the direct impact on nuisance weed growth and the indirect effects on fishery enhancement. The above discussion also poses the hypothesis that juvenile Lake Sturgeon can act as natural predators on larval stages (ammocoetes) of the sea lamprey in the Great Lakes. If this hypothesis is proven with future research then a reasonable approach would be to consider reestablishment of Lake Sturgeon populations in Lake Ontario through stocking, which is now being done in the midwest (F. Binkowski, Univ. Wisconsin, personal communication, June, 1985). The reestablishment of Sturgeon populations in Lake Ontario would provide added benefits beyond its potential for controlling the sea lamprey nuisance. Deep offshore waters of Lake Ontario are thought to support very low densities of fish (J. Elrod, FWS, Oswego; T. Eckery, DEC, Cape Vincent, personal communication, 1985). Further evidence for this contention is the fact that oppossum shrimp (*Mysis*) and amphipods (*Pontoporeia*) are dense in the deep water habitat, suggesting no major predator in these waters. Establishment of sturgeon populations in Lake Ontario may provide a species that will utilize this deep water habitat, further fortifying some of the trophic interactions of the ecosystem and creating more efficient food chains.

The potential benefits of examining biological control methodologies as management strategies should be obvious. Difference in resources expended (i.e., time and money) for reliance on unnatural control mechanisms (*e.g.*, chemical treatment) versus tapping natural environmental characteristics through biotechnology methods, could be significant. Various management groups presently rely on weed harvestors coupled with applications of Diquot, an aquatic herbicide, to eliminate weed nuisances and pesticides to treat lamprey-infested streams. The mechanical harvestor, besides being expensive, damages fish habitat in the lake areas used and Diquot application restricts swimming for up to two weeks after use. Lamprey treatment impacts not only the target species but also the entire habitat. The development of biological control technology as described above would significantly benefit user groups by providing alternative solutions to nuisance problems that emphasize sustainability of the natural environment.

References Cited

Abrahamsson, S. A. A. 1966. Dynamics of an isolated population of the crayfish *Astacus astacus* Linne. Oikos, **17,** 96–107.

Beroza, M. and E. F. Knipling. 1972. Gypsy moth control with the sex attractant pheromone. Science, **177,** 19–27.

Carpenter, J. R., J. J. Elser, and K. M. Olson. 1983. Effects of roots of *Myriophyllum verticillatum* on sediment redox conditions. Aquat. Biol., **17,** 243–249.

Castenholz, R. W. 1961. The effect of grazing on marine littoral diatom populations. Ecology, **42,** 783–794.

Chidester, F. E. 1916. A biological study of the more important of the fish enemies of the salt-marsh mosquitoes. N. J. Agri. Exp. Sta. Bull., **300,** 3–16.

Christie, W. J. and D. P. Kolenosky. 1980. Parasitic phase of the sea lamprey (*Petromyzoo marious*) in Lake Ontario. Can. J. Fish. Aquat. Sci., **37(11),** 2021–2038.

Cooper, D. C. 1973. Enhancement of net primary productivity by herbivore grazing in aquatic laboratory microcosms. Limnol. Oceanogr., **18,** 31–37.

Deangelis, D. L. 1980. Energy flow, nutrient cycling, and ecosystem resilience. Ecology, **61,** 764–771.

Dean, J. L. 1969. Biology of the crayfish *Orconectes causeyi* and its use for control of aquatic weeds in trout lakes. U.S. Bur. Sport Fish. Wildl. Tech. Pap. 24, p. 3–15.

Eck, G. W. and E. H. Brown. 1985. Lake Michigan's capacity to support Lake Trout and other salmonids: an estimate based upon status of prey populations in the 1970s. Can. J. Fish. Aquat. Sci., **42,** 449–454.

Eckert, T. H. 1984. (Draft). Strategic Plan for Fisheries Management in Lake Ontario, 1984–2000. NY Dept. Environ. Conserv., Div. of Fish Wildl., Bur. Fish., Albany, NY, 98 p.

Flint, R. W. and C. R. Goldman. 1975. The effects of a benthic grazer on the primary productivity of the littoral zone of Lake Tahoe. Limnol. Oceanogr., **20,** 935–944.

Frisbie, R. E. and P. L. Adkisson. 1985. Integrated pest management is at hand. BioScience, **35(2),** 69.

Harrison, G. W. 1979. Stability under environmental stress: resistance, resilience, persistence, and variability. Amer. Nat., **113,** 659–669.

Kajak, Z. and J. Warda. 1968. Feeding of benthic non-predatory Chironomidae in lakes. Ann. Zool. Soc. Zool.-Bot. Fenn. "Vanamo," **5,** 49–56.

Lorman, J. G. and Magnuson. 1978. The role of crayfish in aquatic ecosystems. Fisheries, **3,** 8–10.

Loucks, O. L. 1985. Looking for surprise in rearranging stressed ecosystems. BioScience, **35,** 428–432.

Markle, G. E. and S. S. Robin. 1985. Biotechnology and the social reconstruction of molecular biology. BioScience, **35,** 110–226.

Mlot, C. 1985. Managing pesticide resistence. BioScience, **35,** 216–218.

Paine, R. T. and R. L. Vadas. 1969. The effects of grazing by sea urchins *Strongylocentrotus* spp. on benthic algal populations. Limnol. Oceanogr., **14,** 710–719.

Pearce, W. A., R. A. Braem, S. M. Dustin and J. J. Tibbles. 1980. Sea lamprey (*Petromyzon marinus*) in the lower Great Lakes. Can. J. Fish. and Aquat. Sci., **37(11),** 1802–1810.

Risser, P. G. 1985. Toward a holistic management perspective. BioScience, **35,** 415–418.

Sawyer, A. J. 1980. Prospects for integrated pest management of the sea lamprey (*Petromyzon marinus*). Can. J. Fish. Aquat. Sci., **37(11),** 2081–2092.

Scavia, D. 1984. Phosphorous loading and fisheries impact on Lake Michigan water quality. Abstract for the 27th Conf. Great Lakes Research, Brock Univ. St. Catharines, Ontario 29 April–3 May 1984.

Shapiro, J. 1982. Experiments and experiences in biomanipulation. Report #19 from the Limnol. Res. Center, Univ. Minnesota.

Shapiro, J. and D. J. Wright. 1984. Lake restoration by biomanipulation: Round Lake, Minnesota, the first two years. Freshwater Bio., **14,** 371–383.

Shireman, J. V. and M. J. Maceina. 1981. The utilization of grass carp for hydrilla control in Lake Baldwin, Florida. J. Fish. Biol., **19,** 629–636.

Smith, B. R. and J. J. Tibbles. 1980. Sea lamprey (*Petromyzon marinus*) in Lakes Huron, Michigan and Superior: history of invasion and control, 1936–78. Can. J. Fish. Aquat. Sci., **37(11),** 1780–1801.

Spencer, C. N. and D. L. King. 1984. Role of fish in regulation of plant and animal communities in eutrophic ponds. Can. J. Fish. Aquat. Sci., **41,** 1851–1855.

Vanni, M. J. 1984. Biological control of nuisance algae by *Daphnia pulex*: experimental studies, pg. 151–156. *In*: S. J. Downs and J. M. Frazier (eds.), Lake and Reservoir Management, Proc. 3rd Conf. North Amer. Lake Manag. Soc. Monifield, VA 604 p.